

AD-764 607

SELF-REGULATION AS AN AID TO HUMAN EFFECTIVENESS

CALIFORNIA STATE UNIVERSITY

PREPARED FOR

OFFICE OF NAVAL RESEARCH

ADVANCED RESEARCH PROJECTS AGENCY

JUNE 1973

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AD 764607

THIRD ANNUAL REPORT

ONR CONTRACT No. N00014-70-C-0350

AWARDED UNDER ARPA ORDER No. 1595

FOR PERIOD

JULY 1, 1972 TO JUNE 30, 1973

SELF-REGULATION AS AN AID TO HUMAN EFFECTIVENESS



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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) San Diego State University Foundation California State University, San Diego 5402 College Avenue San Diego, California 92115		2a. REPORT SECURITY CLASSIFICATION unclassified	
3. REPORT TITLE Self-Regulation as an Aid to Human Effectiveness		2b. GROUP	
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Third Annual Report, July 1, 1972 to June 30, 1973			
5. AUTHOR(S) (First name, middle initial, last name) William L. Erickson, Principal Investigator			
6. REPORT DATE July 1, 1973	7a. TOTAL NO. OF PAGES 34	7b. NO. OF REFS 0	
8a. CONTRACT OR GRANT NO. N00014-70-C-0350	9a. ORIGINATOR'S REPORT NUMBER(S) ARPA 3 APR		
b. PROJECT NO.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)		
c.			
d.			
10. DISTRIBUTION STATEMENT Approved for Public Release; Distribution Unlimited			
11. SUPPLEMENTARY NOTES		12. SPONSORING MILITARY ACTIVITY Advanced Research Projects Agency 1400 Wilson Blvd. Arlington, Virginia 22209	
13. ABSTRACT This Third Annual Progress Report includes: <ul style="list-style-type: none"> (1) reports of progress made by the individual subcontractors in their respective areas of concentration, (2) publications and papers authored by the subcontractors, and (3) lists of subcontractors and ARPA symposium participants. (U) 			

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This is the Third Annual Progress Report under the contract awarded by the Office of Naval Research to the San Diego State University Foundation under ARPA Order No. 1595 dated March 6, 1970. The goal of this research program is to determine the relevance of physiological processes and internal states for DoD. Under the terms of this contract, subcontracts have been let to 13 universities and research institutes to support specific research projects which are investigating various approaches for self-regulation of physiological processes and the relation of these self-regulated activities to performance. The subcontractors are listed in Appendix 1.

This progress report includes data from the formal written progress reports by each of the subcontractors, material presented during the Third Annual ARPA Self-Regulation Symposium, and the discussions of the ARPA Review Panel following the Symposium.

Overview

During the past year, each of the subcontractors devoted their primary research efforts toward determining the relation of self-regulated EEG and autonomic activity to performance. The specific research efforts will be listed below under the research areas used in previous reports; i.e., Brain Activity, Somatic Activity, Autoregulation of Vasomotor Tone, Cardiovascular studies, Auto-Control of Pain, and Sleep Induction.

Based upon the written and verbal reports, the panel recommended that the major work concerned with brain activity be limited to control of theta activity, particularly the relationship of suppression of theta activity to performance. The results by Jim O'Hanlon, Human Factors Research, and Jack Beatty, UCLA, have indicated that suppression of theta activity may be an effective technique for maintaining performance on a vigilance task. Enhancement of alpha activity or beta activity did not prevent the usual decrements during a vigilance task. Augmentation of theta activity was associated with a significant decrease in performance.

Joe Kamiya will be given a terminal year to complete the work in left-right hemisphere control, and Martin Orne will be given a terminal year to finish his work on the relationship of alpha activity to anxiety. The basic work by Jan Berkhout and Don Walter, UCLA, and Gary Galbraith, USC, in the area of coherence and the self-regulation of coherent brain patterns has been completed and the data do not indicate that further work in this area should continue within the goals of the ARPA Self-Regulation Program. Though Drs. Kamiya, Orne, Berkhout, Walter, and Galbraith have each reported positive results of varying degree with respect to self-regulation of EEG activity, they have failed to demonstrate any clearly significant relationship between self-regulation of brain activity and behavior.

Dr. Taub has successfully demonstrated the utility of self-regulation of skin temperature and the findings of his laboratory will be used as the basis for a program of research of skin temperature control to be undertaken by the Army Research Institute of Environmental Medicine. Dr. Taub will continue in the program for another year, giving particular attention to the use of self-regulation of skin temperature as an aid in the reduction of post-traumatic edema.

While there were questions raised by the panel as to the magnitude of the changes in heart rate reported and as to the significance of the relationship between heart rate and performance, the panel recommended that work in the relationship of heart rate to performance should be supported for one more year. Highest performance on a vigilance task was found to be associated with self-regulated increases in heart rate, with the lowest performance being associated with self-regulated lowering of heart rate.

With respect to self-regulation of pain, the panel felt that Dr. Melzack's work should be continued for another year with particular attention being given to the relative importance of hypnotic suggestions and alpha to the reduction of pain intensity. The data reported by Dr. Melzack concerning the role of alpha was felt by the panel to be questionable at this time.

The relation of somatic activity (i.e., muscle feedback) to performance has been generally insignificant. The work being done by Drs. Stoyva and Budzynski, however, has clearly indicated that muscle activity, particularly coupled with theta activity, can produce lowered levels of arousal and perhaps help in maintaining a reduced level of muscle tension during prolonged activity such as long aircraft flights. In this connection, the Air Force Academy has indicated an interest in a collaborative research program with Drs. Stoyva and Budzynski. Also, the research staff at the Navy Medical Neuropsychiatric Research Unit will, in a modified field testing program, attempt to replicate the sleep-induction techniques worked out by Drs. Stoyva and Budzynski. Self-regulated brief sleep periods, less than one hour, will be used by the Navy Research group to see if effective performance can be maintained during 40 hours of nearly continuous duty.

The coupling of the more basic research-oriented investigators from the universities with performance-oriented laboratories appears to be an effective and efficient way of demonstrating the relation of self-regulated activity to relevant performance tasks. During the next year, the collaboration between the university subcontractors and performance laboratories will be increased. In addition to the collaborative study between Jack Beatty at UCLA and Jim O'Hanlon at Human Factors Research, a collaborative research program will be established between Gary Schwartz of Harvard and Dr. Ben Morgan of the Performance Research Laboratory, University of Louisville; between Drs. Stoyva and Budzynski of the University of Colorado with Majors Chason and Tebbs of the Air Force Academy (with Major Chason serving as primary investigator); and, if a financially feasible research program can be proposed, Drs. Harris and Stephens at Johns Hopkins may provide trained subjects for Mr. Robert W. Smith, American Institutes for Research.

The increased attention to performance tasks and the relation of self-regulation to these tasks were due, in part, to the active consultations of Dr. Earl Alluisi with the subcontractors during the past year. Dr. Alluisi will continue

to provide consultations to the subcontractors and to ARPA during the next year.

The work being done by Dr. Leo DiCara, University of Michigan, and Dr. Wilse Webb, University of Florida, will not be refunded. The basic and exploratory studies outlined in their original proposals have been completed and the results did not indicate that further support is desirable within the limited goals and time period of the ARPA Self-Regulation Program.

The remainder of this report will cover the work done by the individual subcontractors during the past year.

BRAIN ACTIVITY

The work in this area will cover the reports by Dr. Martin Orne, University of Pennsylvania; Dr. Jackson Beatty, University of California, Los Angeles; Dr. James O'Hanlon, Human Factors Research, Santa Barbara; Dr. Joe Kamiya, Langley Porter Neuropsychiatric Institute; Dr. Gary Galbraith, University of Southern California; and Drs. Jan Berkhout and Donald Walter, University of California, Los Angeles.

Martin Orne. The work done by Dr. Orne in close collaboration with Dr. David Paskewitz has been concerned with the potential effectiveness of autoregulation of alpha activity as a technique to increase performance under stress. In his early reports, Dr. Orne has presented data to support his formulation that the consequence of alpha feedback training is different depending upon the mechanism(s) which initially served to depress alpha density. In the study completed during the past year, they sought to design an experimental model which would cause subjects to become anxious after initial baseline values were obtained. Then during the second and third sessions of the study, the subjects would have the opportunity of learning to augment alpha with anxiety serving as the mechanism which should depress alpha activity. According to the hypothesis, anxiety or apprehension would serve to decrease alpha density.

In this study, at the conclusion of the baseline training sessions, subjects

who had at least 25% alpha were asked whether they would be willing to return for a continuation experiment which would involve harmless but quite painful electric shock. It was the intent of the study to create a situation where subjects would be moderately anxious for the succeeding sessions. Dr. Orne felt the manipulation was more effective than he had intended, for only between 20 and 25% of the subjects agreed to return for the shock part of the study. On Day 2, the subjects were given the following instructions: "Now for the next several trials your task will be the same as it has been, that is, to keep the high tone on. During some of the time when the tones are on, however, there will also be a third tone present. Whenever this third tone is present, you are in danger of being shocked through the electrodes attached to your leg. The shocks will randomly vary in intensity, and some will be quite painful, but the number of shocks you receive will depend on you. The third tone I was talking about occurs only when the low tone, that is the nonalpha tone, is on. It is also the case that the shock can occur only when this third tone is on. Furthermore, the probability of a shock is a function of the amount of this third tone since the last shock. Clearly, then, the more you keep the high alpha tone on, the less likely you are to receive a shock. Are there any questions?"

The subjects did not receive more than two shocks bearing in intensity from 1/2 to 3 milliamperes during each of the 5-minute trial periods while the jeopardy tone was on. After the trial, the subjects were debriefed and all subjects returned for a third experimental session which was identical to the second.

The results of the heart rate data and the skin resistance data showed clear autonomic changes indicative of an increase in anxiety during the shock jeopardy trials of Days 2 and 3. Of surprise to Dr. Orne and his staff was the absence of any significant decrease in alpha density during Day 2 and Day 3. There was no significant drop in alpha density during Days 2 and 3 baseline nor was there a significant augmentation of alpha during the feedback period. Indeed, some of the

subjects showed a decrease in alpha density during the feedback period, probably as a function of drowsiness in the dark, comfortable room. There was also no significant decrease in alpha density during Day 3.

On the basis of their findings, Dr. Orne felt that it seemed clear that under some circumstances an increase in the subject's level of anxiety may not be reflected in a drop in alpha density. While there was no significant drop in alpha density, there was a highly significant increase in heart rate and a marginally significant increase in the number of nonspecific electrodermal responses providing strong support for the uniform assertion of all of their subjects that they had felt anxious and fearful at the beginning of the second day.

In an effort to explain their failure to find a clear-cut relationship between alpha density and changes in subjects' anxiety, Dr. Orne divided the alpha group into learners and non-learners. Five subjects were found to have learned to increase their alpha density during the training periods, and five individuals showed no alpha density learning curves. When these two groups were compared, there were suggestive data to indicate that the subjects who showed no alpha learning curve also showed no decrement in alpha density between Day 1, Day 2, and Day 3. The subjects who learned to augment their alpha showed a significant reduction in alpha density. The learners also showed a significant reduction in alpha density during the initial periods in which they were in jeopardy of being shocked. Those subjects who did not learn to increase their alpha showed an increase in heart rate during the shock trials while those subjects who learned to augment their alpha did not show a significant increase in heart rate over the trials. The pattern which tentatively emerges between the learners and non-learners suggests that those individuals who on Day 1 showed evidence for volitional control of alpha density respond differently during the shock jeopardy trials on Day 2. While the alpha densities of the non-learners seem almost totally unaffected by the shock manipulation, the alpha density of learners seemed relatively responsive

to the shock manipulation. The learners appeared to also be able to recover considerably more quickly when exposed to the shock as though they were able to gain control of their general physiological arousal levels more rapidly. The result of this effective recovery was seen both in the lower heart rate and in the fewer number of nonspecific skin conductance responses.

During the next year, Dr. Orne would like to concentrate on further examining the differences between subjects who are able to learn to control their alpha activity and those unable to do so. The question remains whether the difference between the learner and non-learner is a function of personality or a reflection of differential learning skills.

Performance Study: To investigate the effect of alpha regulation on performance, Dr. Orne used a task that involved initially the generation of random numbers, then the generation of random numbers while tracking a moving target using the two-hand coordinator, and finally performing both tasks in the presence of a loud noise. Motivated individuals were asked to perform the tracking task on and in combination with the random number procedure and finally with the addition of the auditory stress. They were then asked to enter the alpha feedback training situation and immediately after the feedback sessions they were again asked to do the performance task outside the alpha situation. The goal of the study was to determine the effects of alpha feedback training on the ability of individuals to function under stress.

Six college-age males volunteered to participate in the study. This session, including the alpha feedback period, lasted a total of 2-1/2 hours. The performance data consisted of measures of tracking efficiency in terms of seconds on target per 2-minute trial. Dr. Orne has developed, from previous work, a measure of randomness which was used as the criterion score for the random number generation task. The data from all the effects of noise and stress on performance and the combination of the two tasks together were consistent with previous findings

in their laboratory, but the effects of alpha training on subsequent performance and on alpha enhancement during performance resulted in no significant increase in any of the measures obtained. These data failed to provide evidence that alpha training improves subjects' ability either on the tracking task or on the simultaneous randomization task in the face of stress. Interestingly, the generating of the random numbers had no effect on maintaining alpha density. Dr. Orne found this finding somewhat surprising, in view of his previous results showing that when subjects were asked to count backwards by sevens there was a significant decrease in alpha density.

Jackson Beatty, UCLA, & James O'Hanlon, Human Factors Research. Since these two investigators have been collaborating during the past year, the results of their work will be presented together. The principal goal for the work by these two investigators has been an assessment of the effects of various types of EEG autoregulation on performance on a simulated radar task. In a pilot study, it was found that subjects were able to maintain alpha (8-12 Hz), beta (14-30 Hz), or theta (4-7 Hz) EEG patterns while simultaneously performing the 2-hour simulated radar task. The most interesting finding during this early pilot study was that the suppression of theta activity had a beneficial effect upon the subjects' vigilance performance. The two pilot subjects' efficiency remained at a maximum level during the watch when they suppressed theta. On the other hand, neither alpha nor beta augmentation had any apparent effect on target detection performance. Based upon these findings, an effort was made to determine whether subjects could be taught to suppress occipital theta activity. Sixteen naive male subjects were drawn from the introductory psychology subject pool at UCLA, and training procedures similar to those previously used for alpha were used for theta training. It was found that subjects could learn to either augment or suppress their theta activity by self-regulation techniques. Based upon the results of their pilot study and the demonstration that subjects could be taught to self-regulate theta

activity, a second study was undertaken to confirm the effects of theta activity suppression on the simulated radar monitoring performance of normal subjects. From the 30 individuals initially screened, two groups of 7 subjects each were selected on the basis of radar monitoring performance. One group was trained to augment, and the other to suppress theta frequency activity. Each group then undertook the EEG regulated monitoring and EEG unregulated monitoring sessions in a partially counterbalanced manner. In the former, both groups performed the radar tasks while autoregulating EEG with appropriate EEG feedback. In the latter, they performed the task without feedback. Work has progressed to the point where most of the data have been collected and preliminary data analysis has begun.

While the data concerning the effectiveness of theta suppression are suggestive, the performance data indicate that those subjects who were told to suppress theta activity required significantly fewer sweeps to detect the target on the radar screen. The theta augment group showed a clear increase in the number of sweeps to detect the target. Drs. Beatty and O'Hanlon feel that these preliminary results appear to have several practical and theoretical implications. Of practical interest was the consistency and the magnitude of the theta suppression effect on radar monitoring performance. Five of the six subjects performed in a superior manner while suppressing theta frequency activity with respect to their performance without EEG autoregulation.

In their original working hypothesis, Drs. Beatty and O'Hanlon implied that a relatively high degree of theta activity would be associated with poor vigilance. It now appears, on the basis of their initial data, that the converse is also true. They would like to expand their hypothesis now to read as follows: "Any procedure which leads to either the suppression or the augmentation of EEG theta activity will affect the performance of individuals performing monotonous work. Theta suppression will improve vigilance-dependent performance; theta augmentation will degrade it." The two investigators will continue their collaborative and

independent studies with the training and control of theta activity and the relation of theta activity to performance. The primary goals of next year's research are to provide procedures and a prototype device for utilizing the technique of theta frequency suppression as a general aid for performance in practical monotonous tasks.

Joe Kamiya. In the past year, Dr. Kamiya, in collaboration with Dr. Jimm Scott, has continued his computer control studies concerned with the relationship of brain activities to performance efficiency. Of particular interest has been the development of computer software and performance tasks to investigate the relationship of feedback training to enhance performance in either the left or right hemisphere. During the next year, primary emphasis will be placed on the extension of work involving fluctuations in the lateral dominance of EEG synchronization during task performance. The objectives will be as follows: (1) To determine the temporal covariation between selective EEG parameters, particularly those indicative of differential hemispheric involvement in tasks known or expected to be predominantly mediated by verbal symbolic processes on the one hand, or by special visual processes on the other; (2) To use feedback training to increase the probability of occurrence of those EEG parameters found to be predictive of superior task performance; and (3) To determine the degree to which task performance is influenced by the EEG feedback training. The specific procedures to be followed will include the following: Performance tasks involving differentiation of hemispheric functions. Left hemisphere tasks will include those dominant for verbal analytic and sequential cognitive functioning. The right hemisphere tasks will include special visual tasks such as a mirror tracking task, tracking a moving oscilloscope target and recognition of faces. EEG analysis will include activity from the left central vs. the left parietal, and right central vs. the right parietal locations. On-line computation of the left-right dominance of alpha activity will be used during the task performance as well as during rest and

control conditions. The feedback training and analog signal will indicate the ratio between activity in the left hemisphere relative to the central region, and the right hemisphere relative to the central region. This signal can be either a continuous AM or FM audio signal, or a discrete binary signal controlled by shifts in the index above and below an arbitrary criterion. Two methods of feedback training will be used. First, the subject will be trained in sessions outside of task performance situations to control the left-right index, and the effect of such training will then be assessed in the task performance. Second, the subject will be given the feedback signal during the task performance. The first will permit the subject to sustain a state of heightened lateral activation preparatory to task performance. The second will permit the subject to monitor any momentary changes in lateral activation that may predict when an error in performance is about to occur, and thus encourage attempts to make whatever corrective central state changes that may be possible for the prevention or reduction of the errors. The performance task, their interfacing to the computer, and the programming of the computer for this project have been completed during the past year, and data gathering is currently in progress.

Based upon preliminary work so far, Dr. Kamiya feels the following tentative hypotheses are warranted: (1) Lateral changes in EEG alpha amplitude are associated with task performances known to involve hemispheric specialization. The lateral shifts are subject to voluntary control through feedback training. (2) Errors of performance on tasks requiring hemispheric specializations are, to some degree, associated with momentary shifts and lateralization of EEG alpha amplitude. In at least some subjects, there may be some regularity in the fluctuations of the left-right index, particularly in resting basal conditions. The nature of these fluctuations and any changes associated with the presentation of the performance task will be evaluated for their potential relevance to performance improvement.

Gary Galbraith. Dr. Galbraith has continued biofeedback training of the EEG cross-spectral frequencies and weighted average coherence patterns to determine whether these two brain measures can be used as predictors of performance. Data collection has been divided between two experiments: (1) On-line biofeedback of weighted-average coherence (\bar{C}), and (2) EEG patterns during paired-associate learning. The purpose of these experiments was to determine, first, whether subjects could exert some degree of voluntary control over complex EEG patterns; and second, whether these patterns might relate to performance in other situations. With respect to voluntary control of \bar{C} , there is evidence that about one-half of the subjects tested ($N = 13$) could exert control, albeit transitory. For a limited number of subjects, a fairly sustained degree of \bar{C} controls seems possible. Experiments still underway suggest that although subjects may have a difficult time controlling mean level of \bar{C} , it may be possible to predict the moment-to-moment fluctuation in \bar{C} .

With regard to the usefulness of \bar{C} as an index of performance during paired-associate verbal learning, the results are merely suggestive. However, the paired-associates task represents only one of many possible tasks. It is entirely possible, therefore, that more positive results might be obtained in other experimental situations.

While Dr. Galbraith believes that some cognitive awareness of covert events may be reflected in \bar{C} , the usefulness of this ability remains doubtful as a tool for ARPA. No further support was requested by Dr. Galbraith.

Jan Berkhout & Donald Walter. During the past year, Drs. Berkhout and Walter have analyzed a total of 72 distinct feedback sessions from 8 different subjects. Their coherence parameters were calculated with a narrow frequency band, 7-8, 8-12, 13-15, and with a constant phase shift across the band being used. The response light of the feedback display was varied from session to session, and turned out to be a crucial factor in the type of effective volitional control that

could be obtained. Their response lag was expressed as a time constant, being the time required for the display to shift from 0.0 to 1.0 coherence when an input from two random generators was replaced by an input to two channels split from a single generator.

With a display time constant of 2 seconds, they obtained good coherence feedback control of "global" occipital alpha with all subjects. This was highly correlated with the traditional measurements of alpha intensity and served as a control for the overall functioning of the display plus subject feedback system. Parietal-vertex alpha coherence was not correlated with alpha intensity in the parietal-vertex channels, and it proved impossible to control parietal-vertex coherence even after the attenuation of alpha in response to the visual display had been habituated.

Many of their sessions were devoted to controlling the 5-7 cycle activity coherence in the left parietal-central x right-parietal-central (LP-Cz x RP-Cz) derivation. Their subjects generally found it possible to lower this coherence value for variable periods but could not maintain a persistent lowering over long periods of time. It was not generally possible to raise coherence values even for a brief period. In view of the subjective strategies employed, Drs. Berkhout and Walter concluded that a subjective stress state adequate to produce the degree of autonomic activation associated with high theta coherence found in other studies was probably never achieved.

Similar results were found for control of 13-15 cycle coherence calculated between the left parietal-occipital x right parietal-occipital (LP-O x RP-O) derivations. Here, too, transient reductions of coherence could be induced by certain subjective strategies, but long-term shifts in coherence levels were not brought under volitional control. The differing subjective strategies used and the difficulties in maintaining long-term shifts in coherence led Drs. Berkhout and Walter to the tentative conclusion that environmental factors (i.e., events related to

tasks and stimuli) are much more potent in determining coherence levels than internally-generated subjective efforts. To the extent the coherence patterns are correlated with performance quality, they believed that this indicated that a self-control model of performance enhancement was not likely to be effective and that the presence of a feedback display was not likely to make it more so.

These general observations were partially confirmed in their unsuccessful attempts to influence reaction time (response to light) by triggering the stimulus only when certain patterns of coherence were present. Spontaneous fluctuations in coherence did not have any apparent influence on reaction time in this context and they have not yet had the opportunity to perform the immensely complex experiment required to control all of the possible effects and then to determine the net effect of such spontaneous fluctuations. However, they have had considerable success in specifying the relationship of 6 and 14 Hz coherence shifts, with performance levels in certain complex tasks. These calculations, however, were all done off-line and were not part of the feedback experiment. The fluctuations in coherence with behavior were quite striking, and Drs. Berkhout and Walter felt that these findings were worthy of being reported. These stimuli or performance-locked fluctuations in coherence were larger than any spontaneous changes noted and exceeded the magnitude of coherence changes which could be produced by volitional control with feedback available to subjects in an essentially passive condition. Thus, in summary, they are still of the opinion that coherence analysis is a most interesting tool for analyzing the central nervous substrates of performance and for evaluating the temporal and epochal constraints of operating on given tasks, but they conclude it is unlikely that enhancement of performance can be achieved by establishing volitional control of these coherence dimensions in a nonperformance environment.

CARDIOVASCULAR ACTIVITY

The work in this area is being done by Drs. Harris and Stephens at Johns

Hopkins University; Dr. Gary Schwartz at Harvard University; and Dr. Leo DiCara at the University of Michigan.

Alan Harris and Joseph Stephens. The goals of the research by this team have emphasized the assessment and evaluation of potential performance enhancement procedures involving autonomic self-regulation. Their work has been particularly oriented toward self-regulation of heart rate in man. In addition to the work with humans, the limits of self-regulation with respect to both organismic capabilities and tolerance level were studied in laboratory baboons to provide appropriate guidelines for human research on such critical questions as duration of maintenance, operational ranges, reversibility, and bi-directional control. During the past year, the work on testing with laboratory primates with respect to control of blood pressure has been completed and terminated. The results of this phase of the project have been reported in previous progress reports. With the completion of the primate studies, work with human subjects has been accelerated to evaluate the effects of heart rate autoregulation in counteracting stress-induced performance decrements under controlled laboratory conditions.

The principal findings from the primate research may be summarized as follows:

- (1) Laboratory primates (baboons) provided with visual feedback of diastolic blood pressure levels can produce large magnitude, sustained elevation of systolic and diastolic blood pressure in a cardiovascular pattern which is characterized by initial increases in cardiac output and subsequent increases in total peripheral resistance.
- (2) Baboons provided with visual feedback for heart rate levels can produce 100% increases in heart rate which are sustained for at least 12 hours per day. Progressively increasing blood pressure during these maintained heart rate elevations again indicates a cardiovascular pattern of increasing total peripheral resistance.
- (3) Continued exposure to the above cardiovascular biofeedback-conditioning procedures may result in chronically elevated cardiovascular levels which persist for weeks and months even in the absence of the instrumental conditioning

procedure. (4) Heart rate and blood pressure lowering procedures are minimally effective in producing subnormal cardiovascular levels, but may be effective in lowering stress-induced cardiovascular increases or in speeding adaptation to sudden and episodic environmentally elicited cardiovascular perturbations.

The methods and procedures used with their human studies concerned with autonomic self-regulation and concurrent task interactions have been described in detail in previous progress reports. Briefly, all subjects are told at the beginning of the experimental program that the researchers are interested in learning whether or not people can control their heart rate voluntarily. Within each experimental session, the subjects are instructed to both raise and lower their heart rates with rest (baseline) intervals separating heart rate autoregulatory periods. Heart rate raising and lowering segments as well as rest intervals are each 10 minutes in duration with an additional 10-minute baseline condition taken at the beginning and end of each experimental session. Auditory and visual feedback of heart rate is provided during the second session and thereafter throughout the experimental program. During selected intervals of heart rate raising, heart rate lowering, and rest conditions, subjects must perform a vigilance task which requires the identification of the letter "X" from among various letters presented at a two per second rate on a display in front of the subject. Correct identifications are reported via a hand switch. Comparisons of performance scores in the presence and absence of heart rate autoregulation permit the analysis of the interaction between these two variables, while the degree of heart rate control with and without concurrent task performance determines the effects of task performance upon cardiac autoregulatory ability.

Superimposed upon both the autoregulation of heart rate and the concurrent vigilance task performance are clicker-shock pairings which represent an additional stress factor in the environment. Each clicker presentation lasts for one minute and terminates with an electric shock applied to the subject's lower right leg.

Three such pairings are presented during a 10-minute interval of heart rate raising, heart rate lowering, or rest, as well as with or without the added concurrent vigilance task performance.

As in previous reports, the investigators showed that the subjects were able to autoregulate their heart rate. Autoregulated heart rate increases for the group averaged 13 beats per minute (bpm) while heart rate decreases averaged 3 bpm, with a range of from 47 bpm increases to 14 bpm decreases. As in the past, the investigators have found that it is easier for the subjects to maintain a larger heart rate increase than heart rate decreases. The 11 female and 29 male subjects in this study were mostly medical and graduate students with a mean age of 23.1 years. A 5-day training period was used. Eight subjects were selected from this sample of 40 subjects for more intensive analyses of the interactions between heart rate autoregulation, concurrent performance, and stress conditions. These 8 subjects showed a baseline heart rate of 76.5 bpm with a mean autoregulated increase to 85.7 bpm and autoregulated heart rate decreases to 74.6 bpm. The highest performance scores (80% correct) were obtained during periods of heart rate raising, while rest intervals with no heart rate regulation showed slightly lower scores (78% correct), and the scores during heart rate lowering fell to their lowest value, i.e. 65%. The reaction times to correct responses during heart rate lowering were clearly the longest, while those during heart rate raising were the shortest and reaction times in the absence of heart rate control fell at an intermediate value. When the clicker-shock pairings were imposed on the task (i.e., there were three 1-minute clickers presented in a 10-minute segment), there was a characteristic reduction in baseline heart rate and also a reduction in the subject's ability to autoregulate heart rate increases. Autoregulation of heart rate decreases, however, were markedly enhanced by the suppressed effect of the superimposed clicker-shock pairings. The heart rate suppression related to the stress elicited by the clicker-shock pairing procedure is consistent with

previously reported findings. The effects of the stress upon the interaction between heart rate autoregulation and concurrent vigilance task performance resulted in the elimination of the subject's ability to produce heart rate decreases and the self-regulated heart rate increase effects decreased to about 7 bpm. A clear interaction between concurrent performance, heart rate autoregulation, and stress was clearly present. During this phase, concurrent performance scores (i.e., percent correct) fell to 73% during rest intervals, and to a low of 60% during periods requiring heart rate decreases. During heart rate increase periods, however, the control (i.e., without stress) performance score of 78% was maintained despite the presence of ongoing clicker-shock stress procedures.

Of all of the conditions, the performance was lowest during the clicker presentations. During periods of heart rate raising, these decrements were essentially eliminated, while during heart rate lowering even greater response decrements were produced. The investigators felt that the counteraction by heart rate raising of the performance decrement shown during clicker-shock pairings was a clear indication of the potential for autonomic self-regulation to provide an effective technique for the prevention of performance decrement that derived from the environmental behavior stress conditions. The investigators, however, indicate that the results must be amplified and reconfirmed, and the proposed research plan for the next budget period provides for such amplification and reverification. While the above results by Drs. Harris and Stephens are suggestive, the differences between the resting heart rate increases and heart rate decrease sessions are relatively small.

As a part of the research during the next year to further investigate whether self-regulation can prevent some of the performance decrement associated with environmental stress conditions, the Alluisi Test Battery will be incorporated as one of the performance tasks, and an evaluation of the interaction between heart rate autoregulation and performance under controlled stress conditions will be

provided by continuous programming 24 hours per day.

Gary Schwartz. This is the first year that Dr. Schwartz has been a part of the ARPA Self-Regulation Program. His study is broadly concerned with the possibility of enhancing performance by (1) training subjects to control relevant patterns of physiological activity through feedback and reward, and (2) to teach subjects to integrate or coordinate the physiological activity with overt behavior by giving feedback and reward for relevant physiological-performance patterns. During this first year, the subcontractor planned to develop on-line computer facilities for defining, tracking, and shaping patterns of responses. The specific patterns were to include blood pressure, heart rate, blood volume, respiration, skin potential, alpha activity, reaction times, and a visual T-scope recognition problem. Depending upon the specific research question, the patterns of regulated physiological variables would vary. Due to uncontrollable administrative delays in initiating the contract and the failure of the computer manufacturer to maintain delivery dates, Dr. Schwartz was unable to achieve the goals outlined for the first year of his contract.

During the second year of his contract, Dr. Schwartz hopes to be able to complete the research outlined to be done in the first year and to train subjects in the control of arousal patterns. It was strongly recommended by the Advisory Panel that Dr. Schwartz collaborate with Dr. Ben Morgan of the University of Louisville. The exact nature of this collaboration is to be spelled out in a revised research proposal to be submitted jointly by Dr. Schwartz and Dr. Morgan.

Leo DiCara. During the past year, Dr. DiCara has been primarily concerned with training of subjects to alter blood pressure responses. While he has reported some progress with respect to self-regulation of blood pressure, the changes are quite small, being in the range of 3 to 4 mmHg. Dr. DiCara feels that a primary reason for this small success was due to the fact that his subjects were bored. Attempts to remedy this by installing a money clock so that each subject

could see how much money he was making was not successful. Based on the reports by some subjects that they felt their hearts beating and could tell when their heart rate and blood pressure would change, Dr. DiCara is currently exploring the possibility of special visual perception training which may enhance the subject's ability to learn blood pressure responses. For example, a subject's blood pressure is recorded on a beat-to-beat basis. Whenever the subject's blood pressure increases above an arbitrary baseline, this is signaled by a "high" tone. Similarly, decreases are signaled by a "low" tone. By imposing a slight delay in the presentation of these tones, subjects are instructed to try and anticipate each tone by moving a lever up for the "high" and down for the "low" ones. These experimental subjects are contrasted with the control group of subjects who receive randomly-chosen tones; i.e., high or low tones independent of actual changes to blood pressure. Preliminary results indicate that subjects probably can be trained to anticipate their blood pressure.

Dr. DiCara has studied whether subjects who were trained in transcendental medication would prove to be better self-regulators than those not so trained. Thus far, the results indicate that training in transcendental meditation has no effect on subsequent ability to learn heart rate responses. In fact, the degree of heart rate response obtained is discouragingly low. Dr. DiCara will attempt to see if there is any difference in ability to regulate blood pressure between those trained in meditation and those not so trained.

Dr. DiCara feels that his results to date indicate that it does not appear possible to obtain learned blood pressure changes of sufficient magnitude to be physiologically relevant. He doubts that it would ever be possible to achieve such large changes in human subjects. Based upon these discouraging findings and the indication that blood pressure changes will require more basic research than originally anticipated, it is not felt feasible to continue with this line of inquiry as a part of the current Self-Regulation Program.

SOMATIC ACTIVITY

The major work in this area is being done by Johann Stoyva and Tom Budzynski, University of Colorado. The main focus of this year's work has been to utilize the training sequence developed earlier in the project to examine the effects of relaxation training (low arousal) on the ability to perform various tasks. These tasks are of two types: (1) those which involve complex decision-making, and (2) those of a simpler, sensory-motor type. Both performance under stress and in the recovery phase after a stress episode are being examined. Specifically, the tasks are as follows:

(1) Complex Decision-Task under Stress

Here the subject is presented with visual slides of I.Q. type problems (Cattell Culture-Fair Test) in which the subject must infer the missing figure in a series of geometric figures. While engaged in this task, subject hears loud distracting noises over his headphones and, at arbitrary intervals, a colored slide of a gory and disturbing automobile accident is presented instead of the usual I.Q. type slide. The objective is to determine whether subjects trained in moderating their arousal levels by means of a cultivated ability at muscle relaxation will perform better (make more correct decisions) than subjects who lack such training.

(2) Simpler Tasks

Since various tasks may be differently affected by relaxation training, Drs. Stoyva and Budzynski decided to explore performance on some simpler tasks in addition to the above complex decision-task.

(a) Maintaining a Pre-Sleep Condition under Aversive Auditory Stimulation.

A central emphasis of their first two years' work was to assist subjects in reaching a sleep-onset condition. At last year's meeting, Drs. Stoyva and Budzynski reported that with a phased training program (EMG training, followed by theta training), normal subjects reliably learned to increase theta above baseline

levels; i.e., to produce a sleep-onset condition. A logical extension of this experiment--which they proposed in their original year 1 application--was to determine whether subjects with systematic training in maintaining theta rhythms will be better able to maintain theta under aversive auditory stimulation than will subjects without theta training. This task is applicable to a situation in which the individual is attempting to rest or sleep under noisy and distracting conditions.

(b) Hand Steadiness Task. Here the task is to hold a stylus as steadily as possible. The subject attempts to hold a metal stylus within a 5mm. diameter hole without touching the edges of the hole. The sequence of events for this test is as follows: first, the subject firmly squeezes a hand dynamometer for 3 seconds; next, he deeply relaxes for 30 seconds; finally, he performs the steadiness task for 30 seconds. Trained subjects (with relaxation training) are being compared with untrained ones.

(c) Subtracting Serial Sevens. Here the individual counts backward by sevens, beginning at a figure of 800. The task lasts 1 minute, and generally serves to arouse the individual. Subjects instructions are to shift back to a thoroughly relaxed condition as quickly as possible after performing this task. Are trained subjects better at shifting to a low arousal condition after exposure to this brief-duration stress? This observation would bear on the question of recovery after stress-induced heightened arousal.

Performance of both experimental and control subjects is being assessed on each of the above four tasks, both before and after training.

Comparisons of Main Interest

(1) On the complex decision-task (inferring the missing part of a pattern series), do trained subjects show faster recovery of performance after a brief stress period than do untrained subjects? (Both groups are given 2 minutes to relax between the stress episode and the immediately ensuing complex-decision slides.)

(2) Are theta trained subjects better at maintaining a pre-sleep condition under aversive noise stimulation than subjects not so trained?

(3) Are trained subjects better at maintaining hand steadiness? (Subject tenses hand dynamometer, relaxes, then does steadiness task.)

(4) After subtracting serial sevens for 1 minute (a mild stressor), can trained subjects shift back to a relaxed condition more quickly?

During the next year of this program, Drs. Stoyva and Budzynski will complete the research began in their laboratory on the effects of muscle relaxation on performance and maintenance of low levels of arousal under aversive auditory stimulation. In addition, a collaborative research with the Air Force Academy is being planned. Majors Chason and Tebbs of the Air Force Academy and Drs. Stoyva and Budzynski are to submit a research protocol detailing the collaborative research program.

PAIN

The work in this area is being done by Dr. Ronald Melzack, McGill University. During the past year, Dr. Campbell Perry has joined the project. Dr. Perry is an Associate Professor of Psychology at St. George Williams University in Montreal and has worked in the field of hypnosis for the last 12 years. The strategies of Drs. Melzack and Perry have been to utilize a combination of alpha feedback, hypnotic suggestion, and relaxation as techniques for relieving pain in one group of subjects. The exact details of their procedures have been outlined in previous progress reports. Other groups are being tested to determine the relative contributions of alpha, hypnotic suggestion, and relaxation for the relief of pain. To date, 25 subjects suffering from chronic pain have been tested. Initially, the clinical patients were selected from a population that suffered severe chronic back pain or arthritic pain for several years and had persistent pain despite dis-surgery, neurosurgical work on cord sections, psychiatric help, or one or more standard physiotherapeutic methods. During recent months, they have extended the

range of clinical patients to include peripheral nerve injuries, phantom limb pain, headache, rectal pain, and chest pain.

The basic procedure to achieve the self-regulation of pain includes baseline recordings, followed by hypnotic instructions, then instructions for alpha training, alpha feedback training, "wake-up" instructions, and then post-baseline recordings followed by practice with alpha "on" and alpha "off" sessions. The subject is told that he will hear music when he produces alpha, and his aim should be to produce as much alpha and thus music feedback as he can. The music feedback consists of the Bach flute music which has been rearranged with a slight jazz beat. They feel that the use of this feedback has been particularly effective in this patient pilot sample. All patients now receive cassettes of the music and are told to use them to facilitate development of an "alpha state" between training sessions.

In addition to the subjects tested with the above combination of the alpha and hypnotic basic procedures, Drs. Melzack and Perry have begun to test subjects with parcellated procedures in order to determine the relative contributions of the hypnotic procedures and the alpha training in the control of pain. Basically, the study is designed with four major groups, each receiving the following conditions: (1) hypnotic procedure plus alpha feedback, (2) hypnotic procedure alone, (3) alpha feedback training alone, and (4) an alpha feedback control group that will receive non-alpha contingent feedback such as beta feedback.

Of the 25 patients tested, 15 completed a sufficient number of training sessions utilizing the hypnotic procedure plus alpha feedback to provide reliable pain questionnaires in alpha data. On the pain questionnaire, these subjects showed a significant decrease on the pain intensity scale during training. The mean percent decreases were 5% during baseline sessions, 44% during the last two training sessions, and 32% during the practice sessions. The data also show that both the sensory and affective dimensions of pain are diminished by the training.

The three patients who stopped after six or eight sessions without completing the entire course of treatment and who felt the training was not helping them were workmens compensation cases.

Many of the subjects took large quantities of analgesic drugs. On their own initiative, three of these subjects decreased their drug intake by 30% and one by 50%. Two of these claimed that they had decreased their drug intake but could not provide a definite figure. Three subjects claimed no change in drug intake. Seven of the 15 subjects felt that the duration of the relief from pain outlasted each training session by one to four hours, and three subjects felt that the pain relief lasted 15 to 30 minutes beyond the training session. There were also indications from some of the patients that they slept better, were visibly happy, and went to parties and met friends which they had not done for years. The number of patients available for comparison of practice sessions after completion of training with pre-training baselines are too small at this time to provide reliable data. Four of seven subjects available, however, received 33% or greater relief of pain during the practice sessions.

While Dr. Melzack feels the results to date are encouraging, he is as yet unable to state the relative contribution alpha training and hypnotic suggestion makes to the decrease in pain intensity. The studies outlined for the next year, in which comparisons will be made of patient groups who receive only hypnotic suggestion or only alpha training or beta training, will perhaps provide some of the answers. It is also hoped that follow-up data will be available on the subjects treated to date to determine the lasting quality of the self-regulation training procedures.

VASOMOTOR ACTIVITY

The principal investigator is Dr. Edward Taub, Institute for Behavioral Research. During the 2-3/4 years since the initiation of this contract, Dr. Taub has developed techniques for enabling most human subjects to establish rapid

operant control of their own skin temperature when provided with immediate feedback information concerning variations in local skin temperature. Nineteen of his last 20 consecutive subjects have been able to learn self-regulatory control of this parameter. Training to a level of unequivocal acquisition rarely required more than 15-minute training periods. After that time, the mean change for 15-minute sessions for all subjects was approximately 2.5°F., ranging up to 6.5°F. Subjects selected for additional training routinely displayed ranges of 8 to 15° within 15 minutes. Retention of this task has been found to be virtually perfect over an interval of 4 to 5 months in four cases. It was also found that after sufficient training, self-regulation of skin temperature was as good without feedback as with feedback. Subjects were also found capable of maintaining a self-regulated temperature response for periods of up to one hour, which is the longest interval that Dr. Taub has used in his testing. Early in training, the temperature response tended to be anatomically diffuse with considerable covariation by the contralateral untrained hand. As mastery increased, the response became more and more localized to the trained portion of the body and eventually developed considerable anatomical localization. However, the localized response can be made to generalize easily to include the whole hand.

Dr. Taub is currently testing a device which will enable learning the continued performance of a generalized response throughout training. He is also currently constructing a scale derived from MMPI to predict ability to self-regulate temperature. The reliability of Dr. Taub's training procedure has reached the point where the self-regulation of skin temperature is now to be tested in the Army Research Institute of Environmental Medicine laboratory. The self-regulation of vasomotor activity is the first of the self-regulation procedures which has advanced to the point where field testing appears feasible. In his own laboratory, Dr. Taub next year will focus his attention on another part of the program outlined in his original proposal; i.e., the reduction of post-traumatic edema. It

is expected that this work will be completed during the next year and this will be the final contract year for Dr. Taub.

SLEEP INDUCTION AND ASSESSMENT OF THE EFFICIENCY OF SLEEP

The principal investigators for this research are W. B. Webb and H. W. Agnew, Jr. The work proposed in their original contract was completed last year and a terminal progress report was submitted. Their statement of work included three experiments.

Experiment 1. This project concerned an investigation of the contention that a 7-1/2 to 8-hour sleep period is a necessary requirement for the maintenance of efficient performance. Male subjects were to maintain a sleep schedule of 5-1/2 hours a night for a period of two months. Sleep and performance measures were to be obtained.

Experiment 2. This project investigated whether sleep deprivation per se or whether activities during the wakeful period are the primary determinants of sleep deprivation effects. The experiment was to compare heavy exercise during sleep deprivation with bed rest.

Experiment 3. This project was concerned with the systematic introduction and manipulation of redundant stimuli as they affect the sleep response. The role of pure physical stimuli (light, sound) on sleep was to be investigated. It was additionally proposed that if these stimuli did affect the sleep response, then hardware would be developed to control the physical stimulus.

During the course of the three years, all three projects were completed.

Experiment 1. Sixteen roommate pairs were selected for a 60-day study. After obtaining baseline EEG and performance measures on one week, the subjects began sleeping 5-1/2 hours each night. Weekly recordings were made on the EEG and performance measures. Fifteen of the 16 subjects completed the full 60 days of the study. The principal effects of the regime on sleep were an increase in stage 4 amount and a reduction of the time spent sleeping in the REM stage. Only the

Wilkinson Vigilance test showed a drop in performance. Overall, the findings of the study would imply that chronic loss of 2 to 2-1/2 hours sleep a night is not likely to result in major behavioral problems.

Experiment 2. Eight young adult males served as subjects for this experiment. During the first week of the study, baseline EEG and performance measures were obtained. In the second week, the subjects were sleep-deprived for two nights while doing heavy work on a stationary exercise bicycle. The third week, subjects were sleep-deprived while resting in bed. Two nights of recovery sleep followed each deprivation period.

The two experimental conditions did not produce differential effects on the recovery sleep night. Further, while the performance measures were generally sensitive to the sleep deprivation, these tests did not differentiate the exercise condition from bed rest.

These data yield some practical conclusions: In operational settings, where sleep loss occurs, it is unlikely that performance decrements can be offset by simply having personnel reduce their activity level. Performance decrements are just as high with a low level of activity as they are with a high level. In the control of the effects of more limited insomnia, it would appear that instructing the person to "lie there and rest" is more reassuring than effective in reducing performance decrements.

Experiment 3. This work consisted of a series of exploratory studies to determine if redundant stimuli affected the sleep response.

First, a review of the literature was made to determine if deafferentation and inhibition can evoke a sleep response. The deafferentation studies reviewed considered brain mechanisms, sleep through relaxation techniques, special effects of monotony, and auditory evoked responses. Related areas of vigilance and sensory deprivation were also reviewed. The literature suggests monotonous stimuli can evoke brief episodic sleep which alternates with wakefulness. More extended

sleep may be induced when the subject feels the need for a distracting stimulus to eliminate introspection.

An experimental series was conducted on 40 young adult males to examine the influence of repeated tones on the latency of sleep onset. The conditions used were: (1) silence, (2) monotonous sound, (3) low-level tones, (4) low-level tones plus counting, (5) low-level tones plus eye opening, and (6) silence with sleep deprivation. The subjects were allowed 30 minutes to fall asleep.

The results of this study showed that no method of stimulus control was spectacularly successful when compared with a night of sleep deprivation. There was some evidence that tones plus counting produced an efficient sleep response but the results were not striking. This line of investigation was abandoned.

The work, however, concerned specifically with sleep onset resulted in considerable clarification of the criteria for measuring and scoring sleep onset.

PUBLICATIONS, PAPERS SUBMITTED, AND PAPERS READ
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- Harris, A. H. Conditioning of blood pressure and heart rate. Paper presented at meeting of American Psychological Association, Honolulu, Hawaii, 1972.
- Harris, A. H., Findley, J. D., & Brady, J. V. Instrumental conditioning of blood pressure elevations in the baboon. In T. X. Barber, L. V. DiCara, J. Kamiya, N. E. Miller, D. Shapiro, & J. Stoyva (Eds.), Biofeedback and Self-Control. Chicago: Aldine-Atherton, 1972.

PUBLICATIONS, ETC. (continued)

Harris, A., Brady, J. V., Findley, J. D., & Gilliam, W. Instrumental conditioning of large magnitude daily 12-hour blood pressure elevations in the baboon. Science (submitted).

Webb, W. B., & Agnew, H. W., Jr. The effects of a chronic limitation of sleep length. (submitted)

Appendix 1

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Appendix 2

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SCHEDULE

THIRD ANNUAL ARPA SELF-REGULATION SYMPOSIUM
JUNE 1-3, 1973
TRAVELODGE, 1960 HARBOR ISLAND DRIVE, SAN DIEGO

Friday, June 1 - Mediterranean Room

8:30 - General comments and administrative report

George Lawrence	Verne Johnson	Mimi Dvorak
Don Woodward	Mike Lewis	Dale Owen

9:00 - Dave Hord & Dick Townsend

9:45 - Coffee break

10:15 - Martin Orne

11:00 - Joe Kamiya

11:45 - Jack Beatty & Jim O'Hanlon

12:30 - Lunch

2:00 - Jan Berkhout

2:45 - Gary Galbraith

3:30 - Coffee - Coke break

4:00 - Johann Stoyva & Tom Budzynski

8:30 - 10:30 PM Alpha Feedback...Enough is enough?

Enoch Callaway (Chairman)

Position Statements: (10-15 mins. each)

Joe Kamiya	Jack Beatty
Martin Orne	George Lawrence

An informal discussion on past, present, and future of alpha feedback.

Saturday, June 2 - Mediterranean Room

9:00 - Ron Melzack

9:45 - Coffee break

10:15 - Ed Taub

11:00 - Leo DiCara (did not appear)

11:45 - Alan Harris & Joe Stephens

12:30 - Lunch

2:00 - Craig Fields

2:45 - Gary Schwartz

3:30 - Coffee - Coke break

4:00 - General discussion - Earl Alluysi (Discussant and Chairman)

Sunday, June 3 - Mediterranean Room

8:00 - 12:00 ARPA Review Panel breakfast meeting